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DIFFERENTIAL VALIDITY OF A DIFFERENTIAL APTITUDE TEST

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Two studies were conducted to examine the role of general and specific ability in predicting performance in military technical training. The first was a principal components analysis of the Armed Services Vocational Aptitude Battery (ASVAB); the second was a series of regression analyses using principal component scores derived from test scores as predictors and final school grades from Air Force technical training as the criterion.

In the first study, 10 principal components were derived using a nation-wide representative sample of American youth. Weights derived from this analysis were used to compute principal component scores for over 78,000 subjects in Air Force technical training in 89 jobs. The first principal component was a general ability factor (g). Some specific ability components were also interpreted.

The subjects for the second study were approximately 78,000 airmen who had taken parallel forms of the ASVAB and completed technical training. Using Final School Grade as the criterion, multiple regressions were computed to determine if g was a potent predictor for all jobs and if predictive accuracy would increase if other principal components, measures of specific abilities, were added to

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the prediction. The regressions were computed from both uncorrected and corrected correlation matrices to properly estimate the $\underline{R}^2$ values. (SDW)

For each of the 89 jobs, the first principal component, g, was the most potent predictor, and for 69 of the jobs, additional principal components increased the coefficient of multiple correlation. The magnitude of the increase in $\underline{R}^2$ was estimated to be about .022 on average. Although this may seem small, practical benefits could be realized when applied to large groups of individuals such as applicants for military service.

SUMMARY

In order to evaluate the contribution of measures of general ability (g) as opposed to specific abilities (s_1, s_2, s_3, ... s_n), two studies were performed. The first determined the elemental components of the Armed Services Vocational Aptitude Battery (ASVAB) and identified its one general ability component and its nine specific ability components.

These elemental components were then used in a second study to predict performance in 89 technical training schools for about 78,000 Air Force recruits. Results of the predictive (regression) analyses indicated that general ability was the best predictor in all jobs but that specific abilities increased predictiveness in about three-fourths of the jobs.

PREFACE

The present effort was conducted as part of our responsibility to improve manpower acquisition for the enlisted segment of the Air Force under work unit 77191846. It is part of an ongoing commitment to produce a quality Air Force for the present and the coming century.

The authors wish to express their thanks to members of AFHRL/MOA for comment and guidance: Drs. Lonnie Valentine, Linda Curran, and Tom Watson, Ms. Linda Sawin, and Ms. Jacobina Skinner.

SSgt Steven Hoffer (AFHRL/SC) is owed a debt of gratitude for his skillful computer programming and data processing. He exemplifies the high quality enlisted force which can be recruited through careful selection.

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I. INTRODUCTION

Ability testing began by focusing on the general ability of the examinee. For the most part, interest in Spearman's g, a single measure of general cognitive functioning, lost popularity as belief in multiple independent abilities increased. However, the emergence of the methods of validity generalization has brought a resurgence of interest in and research on general ability. The role of general ability (g) and specific abilities (s_1, s_2, s_3, ... s_n) in prediction has gained sufficient interest to motivate numerous studies (see Jensen, 1987a), scholarly debate, and publication of a special issue of the *Journal of Vocational Behavior* (Gottfredson, 1986).

Although Sir Francis Galton in 1883 first espoused the concept of general mental ability or g, it was not until 1904 that empirical evidence was analyzed. Spearman (1904, 1927), through the use of factor analysis, found evidence of a single major factor among the positive manifold (correlation) of test scores, and a minor factor or factors he called "s." This structure was found regardless of the nature of the tests administered. The g was found no matter whether the tests were verbal, perceptual, or quantitative; or whether the tests were informational, homogeneous or heterogeneous in external form, psychomotor-perceptual, speeded, or power.

At about the same time, in contrast to Spearman, Hull (1928) proposed that specific knowledge or abilities which correspond to occupational tasks should be used to maximize predictive efficiency. He presented a rationale for differential aptitude tests and the use of job-specific regressions for weighting predictors. He did not, however, provide empirical evidence to support this intuitively appealing procedure.

Faith in the existence of Spearman's g faded between World War I and World War II despite a lack of sound contradictory evidence. L.L. Thurstone's application of the centroid method of factor analysis (1938) found no g and no s but several primary mental abilities which he asserted were unique and not dependent on g. Spearman (1939) reanalyzed Thurstone's data and located g, as did Holzinger and Harman (1938). Thurstone then spent many years trying to develop pure measures of distinct abilities, but these efforts were in vain. A few years later, Thurstone (Thurstone & Thurstone, 1941) admitted that a general factor was required to explain the intercorrelations among his "primary" factors.

After World War II, a hierarchical theory of abilities including g, a set of major and minor group factors, and specific factors was proposed by Vernon (1950). Although some evidence of its suitability was presented by Moursy (1952), the theory failed to be influential and failed to be confirmed in empirical validation research at the time.

A decade later, McNemar (1964) reviewed the evidence for g and s in relation to differential validity in prediction for a representative multiple-aptitude test battery. The evidence from over 4,000 validity coefficients led him to conclude that differential validity could not be found among tests of cognitive abilities and that general ability measures were useful for predicting educational criteria.

Ghiselli (1966, 1973) published a comprehensive study summarizing occupational aptitude test validation studies from the years 1949 through 1973. He concluded that differential prediction existed in his hundreds of studies but he failed to take sampling error into account in his meta-analysis.

Despite the evidence, psychologists continued to believe in the doctrine of specificity and to conduct their studies and practices in accordance with this belief. For instance, military use of differing composites reflects this belief. A change occurred with the rise of validity generalization

(Hunter, Schmidt, & Jackson, 1982), which only incidentally revived the issue. Validity generalization has been criticized (Abrami, Cohen, & d'Appolonia, 1988; James, Demaree, & Mulaik, 1986) and the general versus specific ability studies, therefore, have been less influential because of the argued shortcomings of validity generalization.

As part of the present effort, two studies were completed to determine if the doctrine of specificity holds for Air Force jobs and, if so, to determine what accounts for the prediction of success in Air Force technical training. More specifically the questions asked were: "What are the components of the Armed Services Vocational Aptitude Battery (ASVAB)?" and "Do the apparent specialized abilities measured by ASVAB contribute beyond g to the prediction of technical training performance and if so, by how much?" In order to avoid the putative shortcomings of validity generalization, raw data were used.

The first study estimated the g and s components of ASVAB; the second evaluated their efficacy in prediction. These studies were done with military subjects because the military is the only source of large samples and of so many jobs using a single testing system. The implications extend far beyond the military setting, however, to Government and industry, as Hunter (1984a) has shown through validity generalization of the ASVAB.

II. STUDY I

The purpose of this study was to determine the components of ASVAB. This was done in order to specify the quantities g and s_1 through s_n in the test.

Method

Subjects. The subjects were the 9,173 youths in the normative sample for the ASVAB (Maier & Sims, 1986). Data on this sample were collected in 1980, and are weighted to be nationally representative of the 18- to 23-year-old population. In weighted form, the sample represents approximately 25,000,000 individuals and serves as the normative basis for reporting ASVAB scores.

The Predictor Test. The Armed Services Vocational Aptitude Battery (ASVAB) is the only multiple-aptitude test battery used for qualification and classification for all Air Force enlisted jobs (Air Force Specialty Codes; AFSCs) as well as for all enlisted jobs in the other services. It has been used in its current content and form since 1980.

The contents of ASVAB (Table 1) represent a compromise among the military services in terms of both empirical and rational judgments as to importance for military testing. There are 10 separately timed subtests, eight of which are power tests and two of which are speeded (Ree, Mullins, Mathews, & Massey, 1982). Scores are reported on the metric of a nationally representative normative base of 18- to 23-year-olds collected in 1980 (Maier & Sims, 1986).

Each of the military services aggregates the subtests into composites for selection purposes. The subtests and composites are highly reliable (Palmer, Hartke, Ree, Welsh, & Valentine, 1988) and have been the subject of several validity generalization studies (Hunter, 1983, 1984a, 1984b, 1984c; Hunter, Crosson, & Friedman, 1985; Jones, 1988; Stermer, 1988).

Factor analysis of the ASVAB (Ree et al., 1982) reveals four moderately intercorrelated first-order factors called "Verbal Abilities," "Clerical/Speed," "Mathematical," and "Vocational-Technical Information." These devolve to a single large major factor in a hierarchical factor analysis.

Table 1. **Subtests of the ASVAB**

Subtest	Number of items	Time
General Science (GS)	25	11
Arithmetic Reasoning (AR)	30	36
Word Knowledge (WK)	35	11
Paragraph Comprehension (PC)	15	13
Numerical Operations (NO)	50	3
Coding Speed (CS)	84	7
Auto and Shop Information (AS)	25	11
Mathematics Knowledge (MK)	25	24
Mechanical Comprehension (MC)	25	19
Electronics Information (EI)	20	9

Procedure. There are three common methods for obtaining estimates of g: hierarchical factor analysis, unrotated principal factors analysis, and unrotated principal components analysis. Each proposes a different model of the structure of the variables.

Hierarchical factor analysis (HFA) proposes a model of correlated factors consisting of g, group, and specific factors. It involves all the decisions of factor analysis at each level of the hierarchy. These include factor extraction decisions, estimation of communality, and rotation. Varying decisions can lead to important differences in the solution. Additionally, numerous statistical estimates make the procedure more variable due to sampling error.

Unrotated principal factors analysis makes fewer statistical estimates than HFA and is more robust to tests chosen for analysis (Jensen, 1987b). Principal factors estimates the components of a matrix reduced by the communality of the variables. It accounts for only the common portion, not for all the variation in the matrix, and introduces inferred factors. It proposes a common factors model in which g and s_1 through s_n are orthogonal, and the number of factors can range from one to the number of variables.

Unrotated principal components analysis (Hotelling, 1933a, 1933b) requires the fewest statistical estimates. It neither reduces the dimensionality of the matrix nor does it lead to inferred factors. It is an analytic procedure which estimates the components of a matrix, accounting for all of the variance. Principal components analysis posits a model with orthogonal factors, with the first usually representing g and the other components representing specificity. As with principal factors, it is not a hierarchical model. Principal components is the least affected by sampling error.

In practice, all three methods yield similar estimates of g (Jensen, 1987b). Principal components has the clear advantages of being analytical and least variable due to sampling error, and accounting for the major sources of variation in a matrix.

All three g estimation procedures were applied to the weighted normative sample for ASVAB (N = 9,173 in unweighted form and N = 25,409,021 in weighted form). The principal components were computed, the principal factors were computed with iterated squared multiple correlations as communality estimates, and a hierarchical factor analysis was conducted. Four factors were extracted from a principal factors analysis with iterated squared multiple correlations as communality estimates. An Oblimin rotation followed, yielding four moderately correlated factors which were in turn factor analyzed with a principal components factor extraction. This resulted in a single higher-order factor.

Three estimates of g were computed for each subject in the weighted normative sample. These were scores on: the unrotated first principal component, the unrotated first principal factor, and the higher-order factor. The correlation between the unrotated first principal component and unrotated first principal factor was .999. The correlations between the higher-order factor and the unrotated first principal component and the unrotated first principal factor were both .996. High correlations are not unexpected. Each g is merely one more way to place positive weights on the 10 (positively intercorrelated) subtests of the ASVAB. Wilks (1938) gives an analytic proof that such a set of composites will have positive intercorrelations.

The first principal component, accounting for the greatest portion of the variance of the variables, has been repeatedly shown to be the g component of multiple-aptitude test batteries (Jensen, 1980). Because the principal components are uncorrelated, they are, as Kendall, Stuart, and Ord (1983) suggest, useful for multiple regression.

Results and Discussion

Table 2 shows the matrix of correlations of ASVAB subtest scores from which the components were estimated. All of the correlations are positive and moderate to strong. Ten principal components were derived from the matrix of ASVAB subtest intercorrelations in the normative sample. No rotations were performed and the number of variables was not reduced.

Table 2. Intercorrelations of ASVAB Subtests in the Normative Sample

	GS	AR	WK	PC	NO	CS	AS	MK	MC	EI
GS	---	722	801	689	524	452	637	695	695	760
AR	722	---	708	672	627	515	533	827	684	658
WK	801	708	---	803	617	550	529	670	593	684
PC	689	672	803	---	608	561	423	637	521	573
NO	524	627	617	608	---	701	306	617	408	421
CS	452	515	550	561	701	---	225	520	336	342
AS	637	533	529	423	306	225	---	415	741	745
MK	695	827	670	637	617	520	415	---	600	585
MC	695	684	593	521	408	336	741	600	---	743
EI	760	658	684	573	421	342	745	585	743	---

Table 3 shows the values in the eigenvector. The eigenvalues (also known as the characteristic roots) indicate that there is a strong first factor (g), a relatively strong second factor, and eight successively weaker factors.

Table 4 presents the standard score weights used to generate individual principal component scores. These weights embody the same information as the unrotated principal components loadings; however, the weights are also useful for individual component score generation. Inspection of the loadings proved them to be neither more nor less interpretable than the weights presented in Table 4. Interpretation of these components is difficult for all but the first, which is g (Jensen, 1987b). The second principal component assigns positive weights to NO and CS, the only two speeded tests in the battery, and negatively weights GS, AS, MC, and EI, which are considered to measure trade-technical knowledge. That is, this component positively weights tests on which women attain higher scores on the average than do men and negatively weights tests on which men generally outperform women. Jones (1988) has shown this component to be gender-related.

Table 3. **Eigenvector Analyses**

Factor	Eigenvalue	Percent of variance	Cumulative percent
1	6.39381	63.9	63.9
2	1.28974	12.9	76.8
3	.52171	5.2	82.1
4	.50951	5.1	87.1
5	.28978	2.9	90.0
6	.27006	2.7	92.7
7	.21101	2.1	94.9
8	.205[illegible]	2.1	96.9
9	.16081	1.6	98.5
10	.14846	1.5	100.0

Table 4. **Principal Component Weights Used to Generate Individual Component Scores**

	Principal component				
	1	**2**	**3**	**4**	**5**
GS	.13808	-.11244	-.21982	-.29416	.19523
AR	.13715	.03854	-.39912	.54694	-.02066
WK	.13736	.06649	-.21381	-.64261	-.08976
PC	.12778	.16656	-.31273	-.71570	-.02359
NO	.11291	.38342	.42663	.23843	-1.36760
CS	.09956	.44464	.75816	.03679	1.11560
AS	.10878	-.43374	.60474	-.00918	-.34001
MK	.12965	.12086	-.61486	.64452	.20353
MC	.12448	-.30623	.21087	.39938	.36281
EI	.12857	-.29635	.14351	-.13640	-.00001
	6	**7**	**8**	**9**	**10**
GS	-.88893	-1.05107	.56764	.46367	-1.25618
AR	.26159	.58641	.25640	-1.51740	-1.06178
WK	-.20343	-.35471	.19392	-1.22910	1.53259
PC	1.10958	.48914	-.18581	.83254	-.55741
NO	-.11449	-.39672	-.29306	.20266	-.11527
CS	-.14894	.21[illegible]34	.13184	-.06193	-.04099
AS	.22086	.62982	1.2838	.27471	.26269
MK	-.26607	.28551	.29615	1.16925	1.09690
MC	.89768	-1.19071	-.72807	-.02996	.28081
EI	-.78167	.90823	-1.43032	.09391	-.06884

Component three negatively weights those subtests which would seem most concerned with an academic curriculum and positively weights the speeded and trade-technical measures. Component four positively weights the two mathematics tests (AR, MK) and negatively weights the three highly verbal tests (GS, WK, PC). Principal component seven appears to stress technical information and quantitative reasoning. The remaining components are not so readily interpretable. To keep g as the first principal component, no rotation was performed. Rotation would distribute the g variance throughout the factors (see Jensen, 1987b).

III. STUDY II

The principal components found in Study I represent the measures of general ability (g) and specific abilities (s_1, s_2, s_3, ... s_n). In Study II, their predictive power was assessed using a sample of airmen who completed technical training.

Method

Subjects. In order to have samples large enough to afford sufficient statistical power (Kraemer, 1983) to detect the expected effects of specific validity, AFSCs with greater than 274 subjects were sought. Subjects were all nonprior-service accessions from 1984 through 1988, who had tested with ASVAB parallel forms (Forms 11/12/13) and who had completed basic military training and technical training.

Measures. As found in Study I, the principal component scores of the ASVAB were used to measure general and specific ability. Previous studies of ASVAB validity have used either subtests (Jones, 1988) or composites of subtests (Wilbourn, Valentine, & Ree, 1984).

The Air Force like the other Armed Services aggregates the subtests into composites (Table 5) for purposes of selection and classification. For selection into the Air Force, an applicant must achieve a specified minimum score on the Armed Forces Qualification Test (AFQT), a composite that measures general learning ability. The applicant must also meet a specified minimum sum of the combined scores for the four selector composites: Mechanical, Administrative, General and Electronics (MAGE). Each enlisted job in the Air Force is associated with one or more of these composites. In practice, the composites form a minimum requirement as optimally weighted subtests are used in the automated person-job-match system.

Previous validity studies have usually involved the four MAGE composites (Stermer, 1988) or the AFQT composite (Wilbourn, Valentine, & Ree, 1984), which is used by all the services to measure "trainability." Average uncorrected validities were reported by Stermer to be in the range of approximately .25 to .45 for 37 different AFSCs with high subject flows. Jones (1988) reported subtest validities corrected for range restriction from .38 to .94 for the same 37 AFSCs.

Table 5. **Subtests Contained in Air Force ASVAB Composites**

Subtest	AFQT	Mechanical	Administrative	General	Electronics
GS		X			X
AR	X			X	X
WK	X		X	X	
PC	X		X	X	
NO			X		
CS			X		
AS		2X			
MK	X				
MC		X			
EI					X

For the present investigation, Final School Grades (FSGs) from technical training were used as the criterion measure (see Wilbourn et al., 1984). In most technical training schools, the FSG is the average of four fairly short multiple-choice technical knowledge and procedures tests. However, in order to be eligible to take these tests, work-sample-type tests, frequently called "performance checks," must be passed. In most technical training schools, these

performance checks may be repeated numerous times until the subject succeeds. Some subjects will be removed from technical training for failure to pass the performance check, but no easily accessible records of repeated testing scores exist.

FSGs range from approximately 70 (passing) to 99 (highest). Reliability estimates are not available. Individuals who failed technical training did not receive an FSG and therefore could not be included in the sample.

Recently the use of FSG as a criterion for validation has been criticized because it is not a direct measure of job performance (Green, Wing, & Wigdor, 1988). However, the vast majority of workers do not perform a job until they have successfully completed training. The Air Force, as well as the other Armed Services and large organizations in general, spends millions of dollars per year on training. Better prediction of FSG constitutes an important goal for all of these organizations.

Procedures. Stepwise regressions of FSG on the 10 principal component scores were computed for each AFSC separately, and no set variable entry order was specified. Using a forward inclusion method, principal components were retained in the regression only if they increased the regression and were significant at the $\underline{p} < .01$ level. No practical significance criterion such as an increase in $\underline{R}$ was used because even modest increases in predictive efficiency can be valuable when applied to large groups of individuals.

In order to obtain better estimates of the multiple correlation in the population, the Lawley (1943) multivariate correction for range restriction was applied. The multivariate correction for range restriction requires two assumptions: homogeneity of variance and a linear relationship. The same assumptions are required for linear regression. The regressions were computed within each AFSC on corrected matrices and again no order of inclusion was specified. Regressions using corrected correlation matrices affect only the estimate of $\underline{R}^2$; no changes are to be expected in the vector of partial regression coefficients nor in the standard errors of estimate (see Lawley, 1943). Results are provided for both the restricted and unrestricted cases because as Thorndike (1947, pp. 66-67) notes, the discrepancy between full range (or corrected estimates) correlations and restricted correlations can be large and differing practical decisions could be made. Some researchers are not comfortable with corrections to correlations. However, as Tukey (Mosteller & Tukey, 1988, p. 144) has observed, "It's better to have an approximate solution to the right problem than to have an exact solution to the wrong one."

Results and Discussion

Tous pour un, un pour tous.
A. Dumas

In Table 6, eighty-nine AFSCs are identified, with samples ranging from 274 to 3,930. Males and females were included in all AFSCs, as were members of all ethnic groups. The smallest sample was 274 for the job of Apprentice Structural Specialist (AFSC 55230). The largest sample was 3,930 for Apprentice Law Enforcement Specialist (AFSC 81132). Apprentice Air Conditioning and Refrigeration Specialist (AFSC 54530) and Apprentice Pavements Maintenance Specialist (AFSC 55130) had the highest proportion of males (99.6%) whereas Apprentice Personnel Specialist (AFSC 73230) had the highest proportion of females (48%). Minority subjects were found in the greatest proportion (41%) in Apprentice Administration Specialist (AFSC 70230) and in the least proportion (5.7%) in Apprentice Aircraft Loadmaster (AFSC 11430).

Table 6. **Ethnicity and Gender Percentages for Each AFSC**

AFSC	N	Female	Male	Minority	Non-minority
11430	353	7.93	92.07	5.7	94.3
12230	428	19.86	80.14	26.6	73.4
20130	351	29.34	70.66	17.1	82.9
20230	340	30.99	69.01	13.2	86.8
25130	550	25.09	74.91	15.5	84.5
27230	926	21.92	78.08	19.0	81.0
27430	336	31.55	68.45	27.1	72.9
27630C	669	24.22	75.78	22.1	77.9
27630O	906	27.30	72.70	21.7	78.3
30434	1274	18.13	81.87	16.2	83.8
30534O	569	13.40	86.60	14.9	85.1
30630	358	18.99	81.01	14.5	85.5
30633	291	19.93	80.07	17.2	82.8
32430	657	15.37	84.63	11.7	88.3
32530	402	16.67	83.33	13.4	86.6
32531	568	16.73	83.27	13.4	86.6
32830	554	16.06	83.94	14.4	85.6
32831	524	12.79	87.21	13.7	86.3
32833	474	1.69	98.31	11.0	89.0
32834	276	6.88	93.12	10.9	89.1
39230	463	30.24	69.76	29.1	70.8
41130O	698	13.90	86.10	13.8	86.2
41130A	53	9.07	90.93	10.2	89.8
41130B	337	18.69	81.31	17.2	82.8
41131A	537	.56	99.44	12.1	87.9
42330	876	10.96	89.04	22.4	77.6
42331	376	13.83	86.17	19.7	80.3
42731	427	13.58	86.42	13.6	86.4
42735	756	7.50	92.20	9.8	90.2
452310	334	11.70	88.30	14.1	85.9
452320	416	7.20	92.8	12.0	88.0
452330	373	7.20	92.8	11.5	88.5
45234	3768	5.47	94.53	13.4	86.6
4523XO	1123	8.50	91.50	12.2	87.8
4523XA	377	8.50	91.50	10.7	89.3
4523XB	306	8.50	91.50	13.4	86.6
4523XC	440	8.60	91.4	12.5	87.5
45430A	1821	8.84	91.16	16.9	83.1
45431	2117	11.01	88.99	12.0	88.0
45433	581	11.36	88.67	10.1	89.9
45434	713	8.27	91.73	16.8	83.2
45450A	541	7.02	92.98	19.6	80.4
45730	2651	7.43	92.57	11.7	88.3
45732	2088	6.13	93.87	13.1	86.9
45833	296	13.85	86.15	15.8	84.2
46130	2271	9.95	90.05	18.3	81.7
46230O	3570	5.80	94.20	13.9	86.1
462301	370	5.40	94.60	16.9	83.1

Table 6. (Concluded)

AFSC	N	Female	Male	Minority	Non minority
462302	293	6.10	93.90	13.2	86.3
46230C	384	4.20	95.80	11.9	88.1
46230D	368	7.90	92.10	13.9	86.1
46230E	745	5.40	94.60	13.4	86.6
46230F	827	6.30	93.70	15.9	84.1
46230K	583	5.30	94.70	11.3	88.7
46330	537	5.59	94.41	9.2	90.8
47232	462	8.23	91.77	14.6	85.4
49131	2152	23.37	76.63	8.1	91.9
49231	570	36.67	63.33	36.9	63.1
49330	498	19.28	80.72	17.7	82.3
54232	422	2.37	97.63	18.1	81.9
54530	283	.35	99.65	17.4	82.6
55130	288	.35	99.65	17.7	82.3
55131	570	1.23	98.77	10.5	89.5
55230	274	4.74	95.26	10.0	90.0
55235	278	7.55	92.45	13.2	86.8
56631	291	8.59	91.41	18.2	71.8
57130	2047	1.22	98.78	17.4	82.6
60100	326	22.09	77.91	29.3	70.7
60231	394	36.04	63.96	35.8	64.2
60530	325	46.77	53.23	20.4	69.6
60531	1052	14.35	85.65	28.9	71.1
62330	815	27.85	72.15	28.8	68.2
63130	1651	6.00	94.00	12.6	87.4
64530	3483	33.62	66.38	26.2	63.8
64531	371	31.27	68.73	40.4	59.6
67231	482	41.29	58.71	31.1	68.9
67232	706	42.92	57.08	33.9	66.1
70230	3839	36.39	63.61	41.2	58.8
73230	1603	48.10	51.90	35.3	64.7
81130	3384	10.41	89.59	17.2	82.8
81132	3930	18.27	81.73	19.1	80.9
81132A	549	17.30	82.70	11.7	88.3
81150	687	6.26	93.74	16.9	83.1
90230	2210	38.55	61.45	26.9	73.1
90330	286	30.77	69.23	24.8	75.2
90630	916	35.48	64.52	31.8	68.2
91530	372	39.52	60.48	22.3	67.7
92430	425	33.18	66.82	33.3	66.7
98130	759	37.29	62.71	27.5	72.5

Note. Letter or number suffix refers to subspecialties in an occupation. For example, AFSCs 81132 and 81132A (Security Police) are virtually the same except that only the latter receive dog handling training.

Table 7 provides a description of the characteristics of the entire sample. There was a total of 78,049 subjects. The modal subject was a white male between the ages of 19 and 20, with a high school diploma. A little over 17% had some college experience and fewer than 1% did not finish high school. Table 8 shows descriptive statistics for the criterion for each AFSC. The lowest average FSG was for the Apprentice Environmental Support Specialist (Sanitation) (AFSC 56631) whereas the Apprentice Electronic Warfare System Specialist (AFSC 20230) had the highest. Most and least variable were Security Specialist (Police) (AFSC 81150) and Apprentice Radio Communications Analysis Specialist (Intelligence) (AFSC 20230), respectively.

Table 7. **Educational and Demographic Description of the Sample**

Gender	Proportion	Age	Proportion
Male	82.8	17-18	29.2
Female	17.2	19-20	37.7
		21-22	18.8
		23 +	14.3
Ethnicity	**Proportion**	**Education**	**Proportion**
Black	14.8	Less than High School	.9
Hispanic	2.8	High School Graduate	79.8
White	80.3	College Experience	16.1
Other	2.1	College Graduate	1.3
		Other	1.9

Table 9 shows the results of the stepwise regression analyses both uncorrected and corrected for range restriction. The AFSCs are presented in numerical order, with a brief categorization such as "Aircrew Operations," "Precision Measurement," or "Intelligence." Selection and classification requirements and brief descriptions of the jobs are given in Air Force Regulation 39-1. The order in which the principal components entered the regression equation is also shown.

The column of Table 9 headed "R_g" shows the correlation of g with the criterion. The column headed "R_{g+s}" shows the multiple correlation of the set of significant principal components and the criterion. These two columns are provided for both corrected and uncorrected correlation matrices. The first principal component, g, entered the regression equations first for all AFSCs. In other words, for predicting the training performance criterion, g was uniformly found to be best.

Some differences are observed between the order of variables entering the regression in corrected and uncorrected form; however, principal component 1 (the g component) always entered first. These differences may be due to sampling errors or to the corrected correlation matrices being superior estimates of the variance-covariance among the predictors. Inspection of the vectors of partial regression coefficients shows little difference between the sets for corrected and uncorrected matrices. The same held true for differences in the standard errors of estimate.

Squared correlations are used to determine the magnitude of the common variance of the predictor(s) and criterion. The average squared correlation for the first principal component and the criterion was .2014 uncorrected and .5849 corrected. By adding other principal components (i.e., specific abilities) to g, the average squared correlations were raised to .2240 and .6073 for uncorrected and corrected coefficients, respectively. The increase in the average coefficient of determination was about 2% for corrected and uncorrected coefficients. The maximum difference was about .10, with a standard deviation of .018 for the R^2 differences.

Table 8. Descriptive Statistics for Final School Grades

AFSC	Mean	Minimum	Maximum	Standard deviation
11430	88.184	73	99	5.329
12230	89.619	75	99	4.869
20130	87.877	76	99	4.880
20230	92.254	83	99	3.087
25130	91.080	79	99	4.638
27230	86.403	72	99	5.584
27430	88.792	73	99	5.402
27630C	85.644	70	98	6.027
27630O	86.606	70	99	6.441
30434	90.495	76	99	4.423
30534O	91.230	69	99	5.440
30630	91.399	82	99	3.859
30633	87.598	71	98	5.470
32430	89.011	76	99	4.875
32530	88.886	75	99	4.792
32531	89.461	78	99	4.628
32830	91.182	77	99	4.351
32831	90.271	77	99	4.394
32833	91.525	79	99	3.872
32834	91.094	81	99	4.347
39230	86.210	70	99	6.116
41130O	88.148	75	99	4.527
41130A	87.312	75	99	4.839
41130B	89.113	77	99	3.969
41131A	88.907	76	99	5.011
42330	89.776	74	99	5.308
42331	87.713	75	98	4.696
42731	82.246	63	97	6.339
42735	87.889	70	99	5.777
45231O	91.332	79	99	4.314
452320	91.808	78	99	4.199
45233O	90.903	78	99	4.207
45234	83.000	62	98	6.915
4523XO	91.366	78	99	4.249
4523XA	91.597	78	99	4.067
4523XB	91.183	79	99	4.258
4523XC	91.295	78	99	4.394
45430A	87.181	71	99	5.905
45431	89.242	69	99	5.167
45433	88.752	74	99	5.165
45434	86.804	70	99	6.465
45450A	85.943	70	97	7.906
45730	83.152	60	99	6.785
45732	83.220	60	99	6.774
45833	90.895	77	99	4.157
46130	88.691	72	99	4.970
46230O	88.809	70	99	4.756

Table 8. (Concluded)

AFSC	Mean	Minimum	Maximum	Standard deviation
462301	89.211	75	99	4.603
462302	89.058	73	99	4.523
46230C	87.945	75	98	4.867
46230D	89.166	76	99	4.351
46230E	89.231	74	99	4.651
46230F	89.647	75	99	4.306
46230K	87.043	70	98	5.336
46330	90.117	79	99	4.300
47232	86.552	69	98	5.864
49131	86.613	71	99	5.231
49231	83.154	70	99	6.643
49330	89.036	77	99	4.590
54232	84.182	65	99	6.330
54530	83.205	67	98	6.612
55130	88.087	68	99	5.386
55131	90.067	79	99	3.884
55230	85.038	70	96	5.178
55235	81.989	66	97	6.480
56631	80.973	64	98	7.065
57130	89.805	74	99	4.712
60100	87.721	70	99	6.387
60231	82.685	68	98	6.263
60530	88.612	72	99	5.642
60531	86.140	72	99	5.691
62330	87.601	70	99	5.969
63130	88.584	70	99	5.726
64530	87.488	65	99	6.082
64531	88.216	71	99	6.341
67231	86.220	71	99	6.224
67232	84.271	64	99	6.518
70230	90.341	72	99	5.485
73230	87.268	73	99	5.688
81130	82.321	60	99	6.652
81132	82.539	60	99	5.598
81132A	88.991	70	99	5.814
81150	84.806	60	99	9.298
90230	83.120	64	98	5.204
90330	85.367	74	97	5.283
90630	86.016	66	99	5.405
91530	85.419	72	99	6.003
92430	85.995	72	97	4.651
98130	88.084	75	99	4.767

Table 9. **Regression Analyses of Final School Grades on Principal Components**

	Uncorrected			Corrected		
	Entered			Entered		
AFSC	Principal component	R_g	R_{g+s}	Principal component	R_g	R_{g+s}
Aircrew Operations						
11430	1	.5737		1 4 7 8	.8350	.8460
Aircrew Protection						
12230	1 8	.4415	.4577	1 8	.6840	.6904
Intelligence						
20130	1	.4727		1	.7597	
20230	1 5 4 3	.3932	.4887	1 3 5 2 7	.8164	.8583
Weather						
25130	1 3	.4475	.4816	1 3 2	.8288	.8442
Command Control Systems Operations						
27230	1	.4998		1	.8050	
27430	1	.3989		1	.7311	
27630C	1	.4448		1 3	.7649	.7704
27630O	1 8 3	.4109	.4325	1 3 8 9 2	.7519	.7673
Communications Electronics Systems						
30434	1 4 5 2 3 7	.4185	.4634	1 4 5 3 2 7	.7961	.8178
30534O	1 4	.3764	.3940	1 4	.7168	.7294
30630	1	.4487		1 7 4 5	.8645	.8981
30633	1 4 3 7	.4998	.6068	1 4 3 7	.8645	.8981
Precision Measurement						
32430	1 4	.5268	.5358	1 4 5	.8478	.8575
32530	1 4 2	.4636	.5162	1 4 2 7	.7865	.8312
32531	1 7	.5003	.5134	1 7 4 2	.8483	.8566
32830	1 7	.5212	.5440	1 7 4 3 2 5	.8616	.8784
32831	1 4 7	.4798	.5110	1 4 7	.8441	.8581
32833	1 5	.5308	.5401	1 5 4	.8758	.8803
32834	1	.4879		1	.8347	
Maintenance Management Systems						
39230	1 4	.3143	.3404	1 4 5	.5325	.5573
Missile Systems Maintenance						
41130O	1	.4023		1 7 3 4	.8165	.8245
41130A	1	.4730		1 4 7	.8566	.8635
41130B	1	.3580		1	.7736	
41131A	1 2 10	.5025	.5252	1 2 5 10	.7933	.8097
Aircraft Systems Maintenance						
42330	1 7 4	.5525	.5702	1 4 7 3 2	.7944	.8070
42331	1 2	.4830	.4991	1 2	.7523	.7628

Table 9. (Continued)

AFSC	Uncorrected: Entered Principal component	Uncorrected: R_g	Uncorrected: R_{g+s}	Corrected: Entered Principal component	Corrected: R_g	Corrected: R_{g+s}
42731	1	.5052		1	.8279	
42735	1 7 2	.3860	.4157	1 2 7	.7106	.7223
Manned Aerospace Maintenance						
45231O	1 5	.4710	.4902	1 5 4 3	.8094	.8295
45232O	1 5 7 3	.5330	.5712	1 5 7 3	.8920	.9032
45233O	1 9	.4080	.4278	1 3 4 9	.7944	.8134
45234	1 2 8 7 4 5	.5271	.5445	1 2 8 5 4 7	.7955	.8064
4523XO	1 5 3 7 4	.4710	.5002	1 3 5 4 7	.8373	.8598
4523XA	1 5	.4293	.4481	1 5 3 4	.8141	.8296
4523XB	1 3	.4707	.4980	1 3	.8582	.8660
4523XC	1	.5010		1 7 5 4	.8357	.8482
45430A	1 7 8 10	.4423	.4612	1 7 2 4 8 5	.7052	.7166
45431	1 2 4 7 3 9	.4314	.4774	1 2 4 7 9 3 5	.7320	.7618
45433	1 7 5	.4022	.4534	1 5 7 2 8 3	.6997	.7377
45434	1 2 7	.4852	.5162	1 2	.7059	.7253
45450A	1 7 4	.2342	.2965	1 4 7	.4145	.4484
45730	1 2 5 4	.4898	.5172	1 2 7 4	.7712	.7870
45732	1 2 8	.5056	.5279	1 2 8	.7976	.8109
45833	1 2 8	.4684	.5171	1 2 8	.7365	.7620
Munitions/Weapons						
46130	1 2 8 7 5	.4871	.5189	1 2 8 7 5	.7998	.8097
46230O	1 7 2 8	.4172	.4381	1 2 7 8	.7249	.7333
462301	1	.4284		1	.7386	
462302	1	.4358		1	.7649	
46230C	1	.4724		1 2 4	.7280	.7500
46230D	1 8	.4202	.4443	1 8	.7373	.7449
46230E	1 7 6 2	.4451	.4850	1 2 6 7	.7584	.7731
46230F	1 2 7	.4172	.4512	1 2 7	.7323	.7448
46230K	1 7	.3988	.4114	1	.7052	
46330	1 9	.5879	.5972	1 9 8	.8790	.8836
Vehicle Maintenance						
47232	1 2 3 6	.3819	.4694	1 2 3	.7018	.7549
Communications Computer Systems						
49131	1 5 7 8 3 2	.4244	.4553	1 5 3 7 2 8	.8191	.8318
49231	1 2	.4744	.4851	1 3 2 5	.7759	.7900
49330	1 3 7 4	.4466	.4821	1 4 3 6	.8434	.8577
Mechanical/Electrical						
454232	1 7	.5160	.5341	1 7 4 2	.8134	.8265
54530	1 2	.5746	.5883	1 2	.7990	.8151

Table 9. (Continued)

AFSC	Uncorrected Entered Principal component	R_g	R_{g+s}	Corrected Entered Principal component	R_g	R_{g+s}
Structural/Pavements						
55130	1	.44812		1 5	.7351	.7444
55131	1 2 5	.4863	.5114	1 2 5 3	.7647	.7837
55230	1	.3581		1 8 5	.6695	.6910
55235	1 2	.3887	.4334	1 2	.7413	.7712
56631	1	.5681		1 2	.8278	.8334
Fire Protection						
57130	1 2	.4771	.4826	1 2 5 8	.7727	.7767
Transportation						
60100	1	.2125		1	.7420	.7533
60231	1 3	.4717	.4971	1 3	.7420	.7533
60530	1 7 2	.4316	.4709	1 7 2	.7533	.7720
60531	1 4 7	.4023	.4162	1 7 4	.6851	.6920
Services						
62330	1	.3146		1 2	.6695	.6734
Fuels						
63130	1 7 8	.3128	.3322	1 8 2 7 4	.6365	.6495
Supply						
64530	1 2 3 7 6	.3180	.3710	1 2 3 7 6	.6437	.6719
64531	1 9	.4511	.4670	1 3 2	.7459	.7513
Financial						
67231	1 2 3 7	.4700	.5177	1 3 2 7	.7487	.7738
667232	1 2 3 7	.4586	.5020	1 2 3 7	.7532	.7769
Administrative						
70230	1 2 3 5 7 8	.3813	.4348	1 2 3 5 7 8 4	.6931	.7184
Personnel						
73230	1 2 3 9	.4358	.4703	1 2 3 9 7	.7641	.7842
Security Police						
81130	1 3 4 8 10	.4058	.4245	1 4 3 2 10 8	.7318	.7412
81132	1 4 3 9 2 7	.5012	.5215	1 4 3 2 9 7 6	.8271	.8369
81132A	1 2	.2973	.3172	1 2 5	.6614	.6778
81150	1	.3423		1	.6152	
Medical						
90230	1 3 4 2 8	.5161	.5533	1 3 4 2 8	.8379	.8528
90330	1 3	.4592	.4866	1 3	.7775	.7884
90630	1 2 3 5	.4064	.4566	1 2 5 3	.7660	.7835

Table 9. (Concluded)

AFSC	Uncorrected: Entered Principal component	R_g	R_{g+s}	Corrected: Entered Principal component	R_g	R_{g+s}
Medical 91530	1 3	.3326	.4736	1 2 3 5	.7430	.8077
Medical 92430	1 3	.4903	.5028	1 3	.7769	.7821
Dental 98130	1 3	.3959	.4146	1 3	.7429	.7497

Note. The columns Rg and Rg+s show the correlation for the first principal component (g) and for all principal components entering the regression, respectively.

The lowest uncorrected squared correlation of the first principal component with FSG was .0548 for AFSC 45450A, Aerospace Propulsion Specialist (Jet Engine Maintenance). That AFSC also had the lowest corrected squared correlation (.1718), as well as the lowest squared multiple correlations both uncorrected (R^2 = .0879) and corrected ($\underline{R}^2$ = .2010). Principal components 7 and 4 were added to principal component 1 for predicting the FSG for this job. The increase for adding these two predictors was about 3%. Inspection of the distribution of criterion scores for this AFSC showed it to be highly different from all the others. Most distributions were slightly skewed and unimodal while this one was highly kurtotic, almost to the point of being rectilinear. There is something very unusual about the assignment of final grades to the students in this course and it would appear to reduce predictability.

The job of Apprentice Nuclear Weapons Specialist (AFSC 46330) showed the largest single uncorrected squared correlation for the first principal component (r^2 = .3456) and a slight increase in the squared multiple correlation ($\underline{R}^2$ = .3566) when principal component 9 was added. Corrected for range restriction, these coefficients become .7726 and .7807, respectively, yielding a difference of about 0.8%.

The largest corrected squared correlation with the first principal component ($\underline{r}^2$ = .7956) was for a highly technical Avionics Repair and Maintenance job (AFSC 45232) for the F-16 jet fighter aircraft. That AFSC also showed the largest corrected squared multiple correlation ($\underline{R}^2$ = .8157) when principal components 5, 7, 3, and 1 were included.

Table 10 shows the frequency with which principal components entered regression equations (corrected). Three equations used seven components; the rest used fewer. The modal number of principal components in an equation was two. Among principal components 2 though 10, principal component 2 entered most frequently (48 times); it also entered most frequently as the second best predictor (28 times). This was expected, as principal component 2 accounts for the second largest proportion of variance in the ASVAB. What was not expected was principal component 7 tying with 3 in entering second most frequently (37 times). The two least efficacious predictors were principal components 6 and 10. Neither fared better than third, fourth, or fifth best predictor for any job. In summary, the three most useful specific predictors were principal components 2, 3, and 7, used in 48, 37, and 37 AFSCs, respectively; least useful were principal components 6 and 10, which together made contributions on only 6 of 89 AFSCs.

Table 10. **Frequency of Principal Component Occurrence in Regression Equations**

Principal component	Number of times entered on step number / Step number: 2	3	4	5	6	7	Total
2	28	8	7	5	0	0	48
3	15	13	7	0	2	0	37
4	14	11	6	2	0	1	34
5	7	12	5	1	2	1	28
6	0	1	1	1	0	1	4
7	9	11	10	4	3	0	37
8	4	6	3	2	3	0	18
9	1	0	3	3	0	0	7
10	0	0	1	1	0	0	2
Total	78	62	43	19	10	3	215

Note. Principal Component 1 entered first in all 89 equations and has been omitted from the table. These numbers represent the regressions based on data corrected for restriction due to selection (i.e., the corrected regression).

The number of times that principal component 7 entered regression equations demonstrates the value of investigating the full set of components, as opposed to investigating a reduced set where the reduction is based on some *a priori* rule such as the magnitude of the eigenvalues. Clearly, all components are useful.

Next, the distribution of differences between the squared correlations with only the first principal component and the squared multiple correlations with additional principal components was computed for both corrected and uncorrected correlations. All 89 jobs were included in this analysis in order to estimate the effects of g and s. In both the uncorrected and corrected forms, the average difference was about .022 (.0223 and .0226).

The results of this study indicate that g (the first principal component) was a uniformly potent predictor of the criterion. Specific abilities were found to be of some use. Principal components 2 through 10 were useful in improving prediction in about 78% (69 AFSCs) of the AFSCs, with component 2 providing the greatest predictive utility and components 3 and 7 following closely. Although these results have not been cross-validated, little shrinkage is expected because the sample sizes are so large.

Thorndike (1957) suggested a procedure similar to the principal components method termed "principal composites," which maximizes prediction of a set of criteria by the composites. The first composite would be the most predictive and each succeeding one would be orthogonal to all the others and be decreasingly predictive. Although he was able to demonstrate that the utility of this procedure is analogous to that of the principal components method, two problems make it unworkable for our purposes. First, with thousands of jobs in the Armed Services, the computational burden is excessive. Second, as jobs change, the "principal composites" have to be recomputed. Recomputation is also necessary for the principal components of tests, but tests change less frequently than do jobs in most organizations (such as the Air Force).

The implications for selection are clear. Measures of g are useful for all of the jobs (AFSCs) investigated. There appears to be no reason to believe that this would not hold true for all

AFSCs but many were not analyzed because their samples were too small (see Thorndike, 1986). All Air Force jobs could be described in terms of their g requirement and many in terms of their s_1, s_2, s_3, ... s_n requirements. A system could be developed which clusters AFSCs (Alley, Treat, & Black, 1988) in terms of regression equations of g and s, and bases classification on these clusters. Such a system could keep the form of composites but each composite would be composed of principal component scores. Each job could be assigned to a principal components regression-based composite. The number of such composites, as indicated by Tables 5 and 6, would probably be greater than four but still not too large for practical concerns. Alternatively, all AFSCs could be sequestered by g-level, and then job assignment within g-level could depend on s_2 through s_{10} or applicant preference, predicted job satisfaction, or expected attrition.

Although the increase due to specific components (principal components 2 through 10) was small (.022), when applied across a large organization such as the military, large benefits could be obtained. For smaller samples which allow less statistical power, as found in most industrial validations, the likelihood of finding utility in specific ability predictors is low.

Clearly, the effect of general ability in predicting a technical training performance criterion is very large; but specific components of the ASVAB aid in prediction, if only to a small extent.

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